EROSION MODELLING RESULTS AND EROSION CONTROL DESIGN RECOMMENDATIONS PAD A OPERABLE UNIT 7 IDAHO NATIONAL ENGINEERING LABORATORY IDAHO

Prepared for

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INTRODUCTION

This report summarizes existing erosion and sedimentation conditions at the Idaho National Engineering Laboratory (INEL), radioactive waste management complex (RWMC), and subsurface disposal area (SDA) at Pad A. The findings are based on a visit to Pad A, information provided by INEL personnel, and the application of standard scientific principles and formulas for estimating and assessing erosion and sedimentation. Potential erosion and sediment control measures for Pad A are also described.

The Pad A landfill cover is approximately 3 to 6 feet deep and is composed of a fine-grained soil obtained locally. This soil has a substantial silt and clay fraction, which makes it highly erodible. The landfill slopes are as steep as 1-to-1 with a poor vegetative cover (crested wheat grass).

The two methods chosen to estimate current erosion from the landfill were the universal soil loss equation (USLE), and the modified universal soil loss equation (MUSLE). Both of these models are empirically based and model the soil detachment process.

The USLE was chosen to estimate erosion because it is easy to use and provides a general check of the MUSLE. The USLE is a gross erosion equation that predicts annual erosion using an annual rainfall input parameter. The MUSLE was chosen because it could generate erosion estimates based on site-specific rainfall. Both equations use the same input parameters for vegetative cover, management practices, and slope gradient and length. These parameters are described in detail in Appendix A.

THE EROSION PROCESS

Soil erosion begins with rainfall, the duration and intensity of which affects the amount of sediment moving off site. The USLE model describes rainfall in terms of erosivity units, or EI, which is a statistical interaction term that reflects the combination of the total energy and the peak intensity for a particular storm (Wischmeier and Smith, 1978). The USLE equation predicts erosion over a period of one year; thus the "R" (or rainfall-runoff) factor is the sum of these EI units over one year.

'o control the off-site movement of sediment, it is necessary to control interrill erosion (the erosion of soil from the unconcentrated flow of water) on the uplands. To compare the interrill process to that of sheet flow is hardly applicable. Sheet flow of soil involves movement by uniform thin sheets of water, which in actuality rarely occurs (Meyer 1979). Interrill erosion is the most deceptive erosion process because the flow is not concentrated and considerable erosion can occur without any recognition of the loss of soil (Foster 1982). Unlike rill and channel erosion, detachment within interrill erosion is almost entirely a function of raindrop impact. Since the flow of water is not concentrated in the interrill erosion process, the energy needed to entrain soil particles comes from the rain drops themselves; therefore, intensity of rainfall plays a large role in the interrill process.

Rill erosion can also be defined as the movement of sediment by a concentrated flow of water. The detachment process in rill erosion is primarily caused by the shear energy of the concentrated water.

The interrill and the rilling processes are combined as gross erosion in the USLE and the MUSLE, but are separated into components in most physically based models. The USLE and MUSLE are gross erosion estimate equations that do not take into consideration the deposition of sediment on the up slopes. However, given the steepness of the slopes at the Pad A site, detached soil will likely be transported easily.

MODELING INPUT DATA

As input to the MUSLE equations, precipitation, runoff volume, and peak runoff values were required. In order to estimate site-specific sediment loss, daily precipitation and runoff values were established. Daily precipitation values from 1979 (the year of landfill closure) to 1990 were available from the National Oceanic and Atmospheric Administration (NOAA) climate station at INEL's central facilities area. This station is referenced as Idaho Falls 46W, station number 4460. Daily precipitation data for this station were remotely extracted from the Soil Conservation Service (SCS)/West National Technical Center (WNTC) Central Forecast System (CFS) data base in Portland, Oregon. The period of record for station number 4460 is 1954 to 1990. In order to model 100 years of post-landfill-closure surface water erosion, an additional 89 years (1990 to 2079) of daily precipitation were estimated using the Hydrologic Evaluation of Landfill Performance (HELP) computer model (Schroeder, et al, 1988). Specifically, the built-in weather generator (WGEN) of the HELP model was used in conjunction with default data for Pocatello, Idaho. Daily precipitation estimates were improved by supplying period-of-record normal mean monthly temperatures and precipitation and latitude for the CFA to the WGEN model.

Measured daily precipitation from NOAA station number 4460 and estimated daily precipitation from the WGEN model were combined to produce 100 years of precipitation, or 36,500 values. For this investigation, it was assumed that surface water erosion would most likely be associated with runoff from rainfall rather than snow and snowmelt. Under shallow snowpack conditions, the underlying soil is generally not insulated and the ground is still frozen as snowmelt runoff begins; thus little erosion takes place. Runoff flows from the interface of the receding snowpack and the ground surface. On the other hand, if the snowpack is deep when snowmelt begins, the ground has been insulated from cold weather and the ground surface temperature is higher than the snowpack itself. In this case, snowmelt runoff infiltrates the ground surface before overland flow begins. In either case, one of the largest contributors to the erosion process, raindrop impact and soil detachment, is absent. It is possible to develop annual snowpack profiles and estimate snowmelt runoff so that this runoff is included in the annual erosion estimates. However, this is a complex process and was not part of this investigation.

Using an SCS statistical summary of station precipitation and temperature data (TAPS report) available through the CFS, only precipitation that fell during months where mean temperatures were above 32 degrees Fahrenheit, or approximately from April through October, were used. The 36,500 precipitation values were thus reduced to 18,000 values.

A site-specific SCS runoff curve number was selected and runoff volumes were calculated using the SCS rainfall excess or runoff volume technique (Barfield et al 1981). In conjunction with this technique, the initial abstraction or rainfall lost to infiltration before runoff occurs was also estimated. The depth of rainfall required before runoff began was determined to be 0.29 inch under current Pad A conditions. Therefore, on any day when precipitation values were less than 0.29 inch, no runoff or erosion was assumed. This reduced the 18,000 precipitation values to 469 values (or days) when runoff would occur. Based on the low occurrence of 2 or more consecutive days of rainfall greater than or equal to the initial abstraction value, varying antecedent moisture conditions (AMC) were not accounted for; AMC II (average values from the model for general use) conditions were used throughout the modeled period.

ı addition to runoff volume, peak runoff from Pad A for each day when precipitation is greater than the initial abstraction value was estimated using a modified SCS-TR55 method and a relationship that provides unit hydrograph peak discharges based on time of concentration for the SCS storm type typical of the INEL region (Barfield et al 1981).

A computer model was then developed for estimating daily sediment yield based on the precipitation values and runoff estimates, and on the Pad A sediment loss factors discussed above. Estimated sediment yield values are summarized in Appendix A and Appendix B. The output for the computer model is presented in Table 1 and Table 2. The computer model was designed to be flexible. It can be used to estimate erosion from Pad A under a no-action condition and can also be used to assess the effectiveness of proposed control practice measures.

EROSION ESTIMATES AND DESIGN RECOMMENDATIONS

Table 1 shows the estimates of erosion from the current landfill cap using the USLE and MUSLE with local rainfall conditions. Printouts from the computer model for the current landfill cap are included in Appendix A. As shown in Table 1, erosion rates from the landfill cap are excessive. Because of these excessive rates, the specific components of rill and interrill erosion were not calculated. However, these calculations could be calculated using the Onstad and Foster (1975) method if it is deemed necessary. The following are reasons for excessive erosion:

- The slopes are steep, causing high runoff velocities and subsequently high shear stresses on soil particles, easily transporting detached soil.
- Vegetation is poor, allowing soil particles to be easily detached with intensive rainfall.
- No erosion control practices are used.
- The soil is fine-grained and highly erodible.
- Several landfill slopes are steep at the bottom where runoff accumulates and water velocities are high.

Table 2 shows the estimated erosion rate from the landfill after applying some design changes and using the USLE and the MUSLE equations with local rainfall conditions. Printouts from the computer model for the design changes are included. As shown, the gross erosion estimate decreased substantially because of the following landfill design changes:

- Decreasing the slope steepness to 4 to 1
- Increasing vegetative cover to approximately 50 percent
- Assuming vegetation was planted on the contour
- Assuming slope was smoothly concave not convex

As shown in Figure 1, the erosion rate from the landfill cap is substantially lower with the above modifications in place.

These four landfill design changes could be accomplished by:

- Hauling and placing additional borrow soil to minimize the slope steepness to 4 to 1.
- Using fertilizer to help establish vegetation because borrow soil is obtained from depths up to 10 feet (Huffsmith and Halford 1992) and may be nutrient poor. The field of crested wheat grass next to Pad A provides a good cover, and more moderate 4 to 1 slopes on Pad A would likely maintain soil moisture and provide growing conditions similar to those in the adjacent field.
- Grading the final landfill to a more concave shape (less steep at the toe of the slope) (Huffsmith and Fornstrom 1989) might increase on-site deposition of soil.

In summary, if the slope steepness can be decreased and if good vegetative cover can be established, erosion of the landfill cover would probably not compromise the cap integrity over the 100-year landfill design life.

SUMMARY AND CONCLUSIONS

The excessive erosion at the Pad A landfill is likely the direct result of steep slopes and very little vegetative cover. Erosive rainfall detaches soil particles, and steep slopes easily transport the detached soil. Slope steepness is excessive enough to create water velocities that detach and transport soil during the overland flow process (rill erosion). The erosion process was modeled in is study using local rainfall conditions as inputs into the USLE-based soil-loss equation and modifications of that equation. The results showed that the site would eventually (within a 100-year period) experience a cover failure caused by excessive erosion.

Moderating the steepness of the slope would slow water velocities and help minimize detachment during overland flow. Establishing a good vegetative cover will minimize the erosive effects of rainfall energy prior to raindrop impact with soil and will also slow overland flow velocities. In addition, a good vegetative cover would more effectively use water stored in the unsaturated zone. INEL officials should check with local agricultural experts to see what vegetative cover is most easily established and what fertilizer application rates should be used. If a good vegetative cover is established and slope steepnesses are modified, according to the USLE-based equations, erosion and subsequent discharge will be minimal during the 100-year landfill design life.

TABLE 1
ESTIMATED EROSION RATES: NO ACTION

USLE		
Time from Closure (years)	Estimated Sediment Loss (tons)	Estimated Sediment Loss (inches)
1	8	0.36
10	1,977	3.6
25	4,945	9
50	9,886	18
100	19,772	36

MUSLE (using local rainfall in computer model)		
Time from Closure (years)	Estimated Sediment Loss (tons)	Estimated Sediment Loss (inches)
1	333	0.61
10	1,340	2.44
25	2,253	4.10
50	5,924	10.79
100	9,841	17.92

TABLE 2

ESTIMATED EROSION RATES: CONTROL PRACTICES APPLIED

USLE		
Time from Closure (years)	**Estimated Sediment Loss (tons)**	**Estimated Sediment Loss (inches)**
1	7	0.01
10	72	0.13
25	181	0.36
50	326	0.65
100	723	1.31

MUSLE (using local rainfall in computer model)		
Time from Closure (years)	**Estimated Sediment Loss (tons)**	**Estimated Sediment Loss (inches)**
1	6	0.01
10	16	0.03
25	23	0.04
50	67	0.12
100	110	0.20

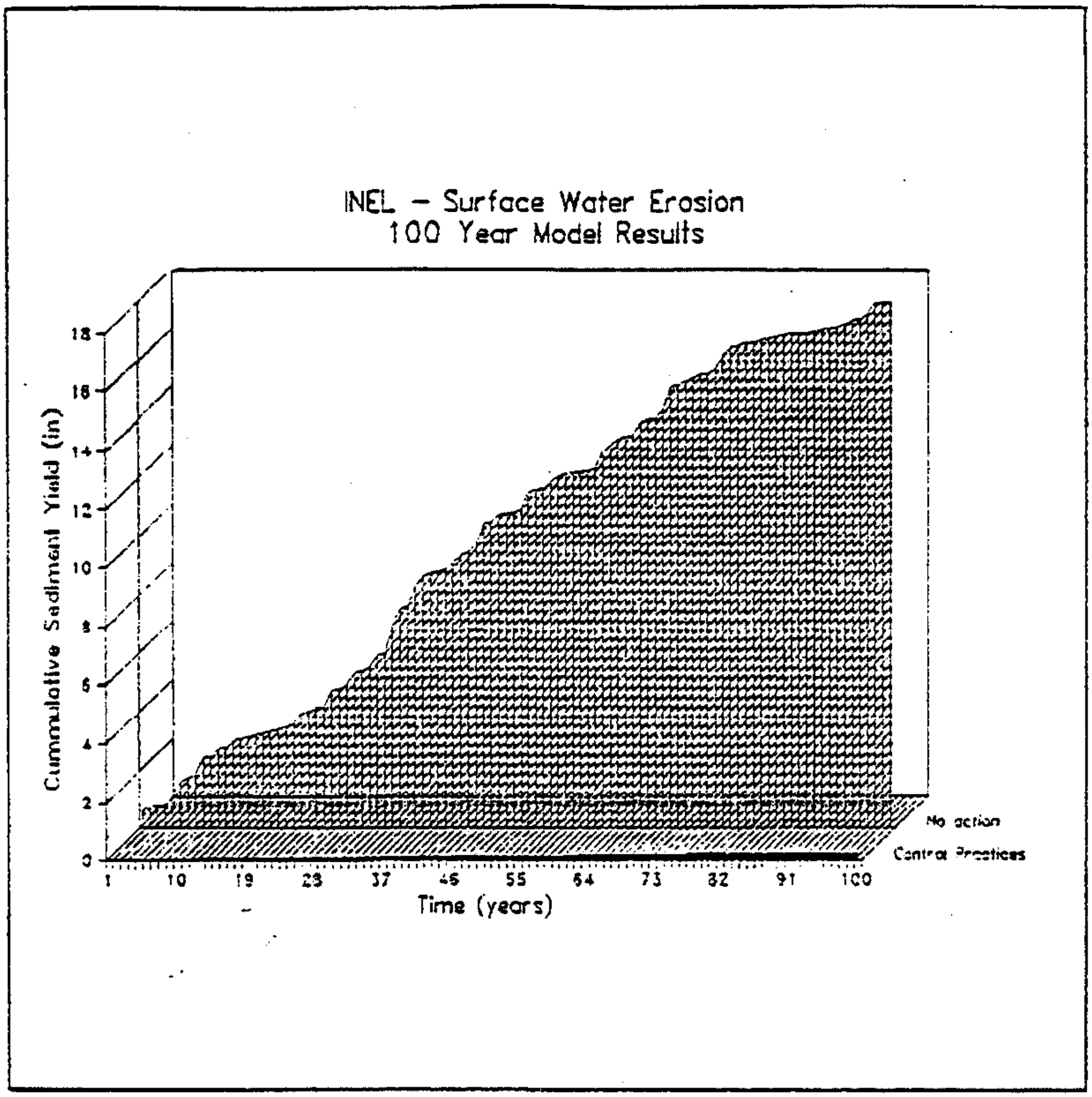

Figure 1 FIG1.PIC

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APPENDIX A

SURFACE WATER EROSION MODEL

NO-ACTION SCENARIO

SURFACE WATER EROSION MODEL
INEL - PAD A
MODEL INPUT PARAMETERS
AND VALUES

NO ACTION

General Input

Pad area:	From RI/FS exhibit showing RWMC, SDA. 300' X 400' = 120,000 ft^2 = 2.75 acres
Maximum flow length:	Hydraulically most remote point in watershed to watershed outlet. From RI/FS exhibit showing RWMC, SDA. = 200 ft
Elevation difference:	From RI/FS exhibit showing RWMC, SDA. 5035 ft - 5010 ft = 25 ft

Hydrology Input

SCS runoff curve number:	Clay/silt/loam = Hydrologic Soil Group C/D Crested wheat grass = range/pasture; poor condition. CN = (86 + 89) / 2 = 87.5 (Barfield 1981)
S parameter:	S = (1000 / CN) - 10 = 1.43
Initial abstraction:	I_a = 0.2S = 0.29

Sedimentology Input

Soil erodibility:	The rate at which soil is lost per erosion index unit on a plot 72.6 ft long and a uniform slope steepness of 9 percent, clean tilled continuously. Based on visual estimate of percent fines and calculated from USDA Handbook 537. = 0.51
Cover factor:	The ratio of soil loss of a specific field with vegetative cover to that of identical clean and smoothly tilled field, tilled up and down the slope. Calculated from USDA Handbook 537. = 0.33

,ngth slope factor:	The ratio of soil loss from the field slope length to that from a 72.6 feet length under identical conditions. From RI/FS exhibit showing RWMC, SDA. Moderate slope = 8.75 Steep slope = 21.35
Conservation practice:	The ratio of soil loss from a field with some practice such as contour furrowing to that of identical conditions yet clean and smoothly tilled up and down the slope. This assumes planting and using equipment on the contour. Currently 15 percent cover and no management practices. Calculated from USDA Handbook 537. = 1.00

APPENDIX B

SURFACE WATER EROSION MODEL

CONTROL PRACTICES APPLIED

SURFACE WATER EROSION MODEL
INEL - PAD A
MODEL INPUT PARAMETERS
AND VALUES

CONTROL PRACTICES APPLIED

General Input

Pad area:	From RI/FS exhibit showing RWMC, SDA. 300' X 400' = 120,000 ft^2 = 2.75 acres
Maximum flow length:	Hydraulically most remote point in watershed to watershed outlet. From RI/FS exhibit showing RWMC, SDA. = 200 ft
Elevation difference:	From RI/FS exhibit showing RWMC, SDA. 5035 ft - 5010 ft = 25 ft

Hydrology Input

SCS runoff curve number:	Clay/silt/loam = Hydrologic Soil Group C/D Crested wheat grass = range/pasture; fair condition. CN = (80 + 84.5) / 2 = 82.25 (Barfield, 1981)
S parameter:	S = (1000 / CN) - 10 = 2.16
Initial abstraction:	$I_a = 0.2S = 0.43$

Sedimentology Input

Soil erodibility:	The rate at which soil is lost per erosion index unit on a plot 72.6 ft long and a uniform slope steepness of 9 percent, clean tilled continuously. Based on visual estimate of percent fines and calculated from Soil Erodibility Nomograph Handbook, p.537. = 0.51
Cover factor:	The ratio of soil loss of a specific field with vegetative cover to that of identical clean and smoothly tilled field, tilled up and down the slope. Calculated from USDA Handbook 537. = 0.06

Length slope factor: The ratio of soil loss from the field slope length to that from a 72.6 feet length under identical conditions. From RI/FS exhibit showing RWMC, SDA.

= 5 (4:1 slope @ 80')

Conservation practice: The ratio of soil loss from a field with some practice such as contour furrowing to that of identical conditions yet clean and smoothly tilled up and down the slope. This assumes planting and using equipment on the contour. Assumes 50% cover with management practices applied.

Calculated from USDA Handbook 537.
= 0.85